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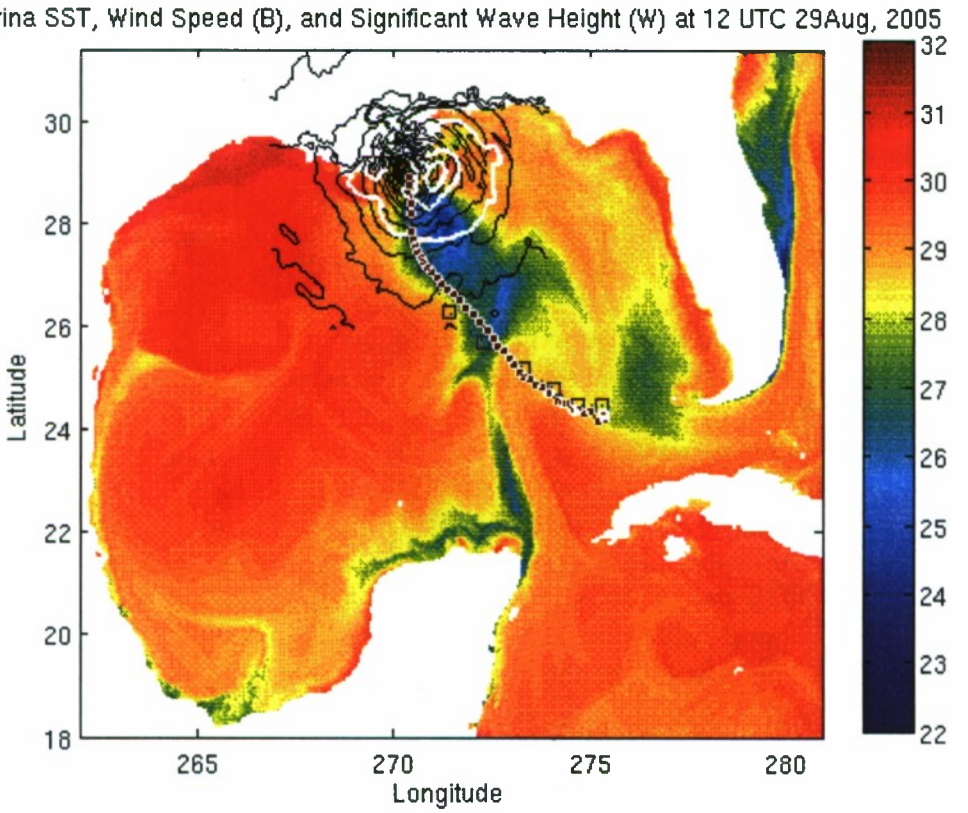
COAMPS high resolution three-way air-ocean-wave hurricane simulation



The image above shows a Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) 48-hour simulation of hurricane Katrina. The three-way coupling between COAMPS, the Navy Coastal Ocean Model (NCOM), and the Simulating WAves Nearshore (SWAN) model is achieved through ESMF. This simulation uses three atmospheric domains, two ocean domains, and one wave domain. The innermost atmospheric nest automatically translates along with the storm. COAMPS predicts a cold sea surface temperature anomaly (degrees C, color shaded area) to the right of the hurricane track in response to the passage of the hurricane's high wind speeds (m/s, black contours). The significant wave height (m, white contours) shows increased wave growth on the northern quadrant of the hurricane due to wind-wave-current coupling effects. The white squares denote the observed location of the eye at six hourly intervals and the dotted line denotes the model location of the eye at hourly intervals beginning at 1200 UTC 27 August. *Image courtesy of Sue Chen, Naval Research Laboratory.*

Table of Contents

Executive Summary

The Earth System Modeling Framework (ESMF) is in its seventh year, and its component interfaces have been implemented in most of the prominent climate and weather codes in the U.S.: CCSM, WRF, NASA GEOS-5, EMC GFS/NEMS, NRL COAMPS and the GFDL MOM4 ocean (*see Appendix A for a table of acronyms*). In general, componentization with ESMF has been implemented at the level of major physical domains, where simulated interactions require inter-component data communications (e.g. atmosphere, ocean). This implementation is compatible with codes such as WRF that impose their own interoperability conventions at the level of individual physics parameterizations.

The codes listed above, plus the full GFDL modeling system under FMS, can now operate within a component-based, hierarchical architecture in which large-scale components can be called as subroutines. This was not the case when ESMF began. The current level of ESMF adoption represents a major and necessary step towards enabling U.S. centers to exchange large-scale components, and is an excellent basis for further advances in code interoperability.

The technical focus of 2009 was on continued development of ESMF grid classes and a regridding capability. These are built on a base of two flexible data representations that were constructed in previous years: an unstructured finite element mesh library and a general array class designed to support fields on logically rectangular grids. At this point ESMF can produce non-conservative interpolation weights, in parallel or serial, 2D or 3D, for grids that can be represented by triangles or quadrilaterals. Users can also read in external interpolation weights, from a package such as SCRIP, if they need an interpolation option ESMF does not provide.

The organizational focus of 2009 was on moving the ESMF core development team and members of the ESMF sister project Earth System Curator from NCAR to NOAA ESRL/CIRES. These staff members now comprise the NOAA Environmental Software Infrastructure and Interoperability (NESII) group. This involved transferring ten project members along with infrastructure such as websites and mailing lists. The strategic motivation for the move was better positioning of the development team with respect to its growing base of operational and other federal center users.

On the applications side, there were several main activity areas in 2009: completing unstructured mesh methods and C interfaces for a BEI coupling project, starting to address issues related to running ensembles with the NASA GEOS-5 model and NEMS, and completing the implementation of ESMF in CCSM in time for the first releases of CCSM4 in early 2010.

ESMF management participated in the definition of two programs: the National Unified Operational Prediction Capability (NUOPC), a collaboration that is developing a multi-model ensemble for operational NWP; and the NOAA Global Interoperability Program

(GIP), a broad collaboration that addresses software infrastructure across a set of high-priority activities including CMIP5/IPCC AR5. ESMF is an integral part of both programs and funded work will begin in 2010: for NUOPC, development of component and coupler templates; and for GIP, more advanced use of ESMF in CCSM and assimilation of the NASA MAPL usability layer into the main ESMF distribution. Under a new TeraGrid project and GIP, the ESMF team will be working with NCAR and Purdue University on a friendly web-based interface and workflow system for CCSM and potentially other climate models, based on a Purdue CCSM Portal that is currently used in their university courses. A recently awarded three year grant from NSF will also enable the Curator and ESMF teams to partner with GFDL, ESG, University of Michigan and the CSDMS hydrology consortium to develop on-line governance functions for community modeling projects.

Major accomplishments during 2009 included:

- Delivery of ESMF v4.0.0r, in October 2009. This release contained a close to complete implementation of the Grid class and regridding capability.
- Inclusion of ESMF interfaces for major components in the alpha release of the Community Climate System Model 4 (CCSM4) in January 2010. CCSM4 also uses the ESMF off-line, higher order regridding package for its standard non-conservative remapping.
- Successful movement of the ESMF core team from NCAR to NOAA in November 2009.
- Initial agreement on organizational changes, reflected in a new draft of the *ESMF Project Plan,* that enable ESMF to operate at a federal center, and that reflect its role in NUOPC.

With respect to the ESMF strategic goal of furthering the integration of models and data portals, the Curator project delivered a metadata display capability for CMIP5/IPCC AR5 that will be included in the next public ESG Gateway release. This links the CMIP5 datasets to comprehensive descriptions of the models that generated them. This work was done in collaboration with ESG, GFDL, PCMDI, a host of European centers, and other collaborators under the auspices of the GO-ESSP consortium.

1 Introduction

The Earth System Modeling Framework (ESMF) was motivated by the growing complexity of building and coupling Earth system models. ESMF provides a set of standard software interfaces and high-performance tools for common modeling functions, thereby promoting interoperable software systems and code reuse. It has transitioned from its initial NASA sponsorship to multi-agency support and management. It is the technical basis for the DoD Battlespace Environments Institute, the NUOPC, the NASA Modeling Analysis and Prediction Program (MAP), and a host of smaller programs and projects. One of its offshoots is the Earth System Curator project, which has focused on creating end-to-end workflows involving high performance models and data distribution portals. More information about ESMF and its applications is available on the ESMF website, http://www.earthsystemmodeling.org; Curator is at http://www.earthsystemcurator.org, and a summary of projects is provided in Appendix C.

2 Software framework description

ESMF components are arranged in a hierarchical structure to form modeling applications. The current ESMF distribution contains:

- Tools for building scientific components and couplers, and a set of utilities for common modeling functions (e.g., calendar management, data communications)
- Scalability of core communication routines to tens of thousands of processors
- Concurrent or sequential execution, single or multiple executable modes
- Support for configuring ensemble members sequentially or concurrently
- Fortran interfaces and complete documentation, select C interfaces
- Support for 30+ platform/compiler combinations, including IBM, Cray XT, SGI, Linux, Mac, Windows, and other platforms. The complete list is available on the ESMF website.[1]

3 Timeline and strategic objectives

ESMF strategic objectives are described in detail in the *ESMF Strategic Plan for 2008-2010*[2]. As outlined in the *Plan*, there are currently three main activity areas:

1. Completing the functional requirements of the framework and improving its ease of use
2. Developing capabilities and strategic partnerships that help to integrate the framework into end-to-end computational environments (science gateways)
3. Supporting users who are integrating ESMF into applications.

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[1] http://www.earthsystemmodeling.org/download/platforms/
[2] http://www.esmf.ucar.edu/plans/plan_0802_esmfstrat.doc

ESMF's second funding cycle, under NOAA, NASA, DoD, and NSF sponsors, will be completed at the end of 2010. Over the next year, the ESMF group anticipates one more major release increment: ESMF 5, which will focus on standardization of interfaces and ease of use. ESMF interfaces after version 5 will be backwards-compatible so that updating to new versions should not require user code changes. Other deliverables in this time frame will include new and enhanced science gateways that build on ESMF concepts, capabilities and components.

The ESMF team will begin work in 2010 under two programs, GIP and NUOPC, which will help to shape future strategic objectives. The ESMF organization will experience some organizational changes due to its relationship with these programs and to the move of the core development team to NOAA in late 2009. An updated version of the *ESMF Strategic Plan* covering 2010-2015 will be prepared this year.

All ESMF activities remain rooted in the project's core values of community ownership, distributed development, and open access to information.

4 Accomplishments in brief for FY2009

Framework development. During 2009, the ESMF team was able to build rapidly on mesh and array data structures that had been redesigned for greater flexibility during the previous two years. One of the highlights of a new public release, ESMF 4.0.0r, is a remapping utility that produces interpolation weights, in parallel or serial, 2D or 3D, for grids that can be represented by triangles or quadrilaterals. The remapping utility supports bilinear or higher order weights. A conservative algorithm is being developed for release in 2010 in collaboration with mathematicians from NCAR's IMaGe group.

Science Gateways. The Curator teams partnered with the DOE-funded Earth System Grid (ESG) project, GFDL, the E.U. METAFOR project and others on development of a metadata display for CMIP5/IPCC AR5. This links the datasets associated with CMIP5 with comprehensive scientific and technical descriptions of the models used to generate them. This is an important improvement over AR4, for which relatively little on-line information was available. The display will also be applicable to other model intercomparison projects, and builds on a prototype gateway constructed for a 2008 NCAR ASP colloquium in which a number of atmospheric dynamical cores were compared. The display has been included in initial releases of a new version of ESG and will be part of its next major public release, currently scheduled for delivery in March 2010.

Student visitors contributed prototypes for the interaction of ESMF codes with data portals. One showed that a code instrumented with ESMF could produce time series metadata that conformed to the requirements for a hydrology data portal. One collaborated with NRL to produce a version of COAMPS that was instrumented with model metadata. Another instrumented CCSM with metadata, then embedded that version in an automated workflow that configured the model, ran it, and documented the run. These projects are building towards an increased level of automation and semantic interoperability that will be an important element of the next ESMF development cycle.

ESMF applications. The current estimate is that the number of available science components has grown from 69 at end FY2008 to 90 at end FY2008. A full listing of components is available on the ESMF website.[3]

5 Plans in brief for FY2010

Framework development. The focus for 2010 will be on completing the scope of work under current awards, preparing ESMF for deployment at operational centers throughout the U.S. as part of the NUOPC program, and planning ahead for the broader goals of the GIP program.

The current *ESMF Strategic Plan* describes a number of development tasks that remain to be completed before the end of 2010:

- Completing multi-tile grids and exchange grids
- Completing a conservative regridding capability
- Completing a basic but usable I/O system
- Completing a component compliance checker

In addition, during 2010 the development team will focus on standardization of interfaces and behavior across the framework, documentation, and the development of training materials.

The ESMF team will also begin work on new NUOPC, GIP, and TeraGrid projects. Development of the NUOPC usability layer will commence with the construction of component and coupler templates. Projects under GIP include integrating MAPL into the main ESMF source distribution, so that these capabilities are supported by the ESMF team rather than NASA, and continued integration of ESMF into CCSM. New CCSM work includes exploration of the ways that ESMF regridding can be used within the model.

Science Gateways. The Curator collaboration will continue development of the metadata display for CMIP5/AR5, addressing any issues that arise after it is fully deployed.

Under both TeraGrid and GIP funding, Curator, Purdue and ESG collaborators will develop a GUI and workflow system for climate modeling based on the Purdue CCSM Portal. This Portal, already used in classes at Purdue, enables CCSM to be configured easily, and future work will allow metadata and model output data to be archived back to ESG.

The Curator team will also begin work on a new NSF award to develop the idea of "commodity governance," which involves embedding group workspaces and administrative and management functions into gateways to that distributed teams involved in community modeling can self-organize more effectively.

[3] http://www.esmf.ucar.edu/components/

ESMF applications. In 2010, a high priority will be on ensuring that modeling applications for the Battlespace Environments Institute are completed as the program draws to a close. Optimizations for GEOS-5 and the public release of CCSM will be implemented. Special attention will be paid to new customers such as the NCAR High Altitude Observatory TIMEGCM model developers, who have started using ESMF regridding, and customers who have been waiting for ESMF capabilities to become available, such as the developers of the ROMS ocean model.

6 Detailed accomplishments for FY2009

During FY2009, the ESMF team made significant advances in software development; training and support; and community adoption. The following sections describe metrics of success and accomplishments in detail.

6.1 Develop software for grid representation and regridding

Measures of success:

- Delivery of ESMF releases capable of representing multi-patch logically rectangular grids, unstructured grids, and observational data streams.
- Delivery of an ESMF release that generates regridding weights internally and can perform regridding using those weights.

Actual performance, outputs and outcomes:
Work in FY09 on unstructured grids has included continued interaction with BEI staff working on the pWASH123-ADCIRC coupling, provision of necessary interfaces to complete this coupling, including C interfaces, improvements to the unstructured grid (Mesh class) documentation and more Mesh usage examples, and various bug fixes. Bugs have tended to be caused by non-portable C++ features used in the Mesh implementation, which are being replaced or corrected. Regridding to/from fields built on unstructured grids has been demonstrated and the documentation and examples now include examples of this. The Mesh code and regridding software supports meshes with elements that can be represented as triangles or quadrilaterals, in 2-D or 3-D. Improvements to the Mesh software are included in public release ESMF v4.0.0r, which was released in October 2009.

A conservative regridding strategy has been implemented in test code. It performs a local conservative correction to an interpolation algorithm of choice, where current options in ESMF are either bilinear or higher order. An advantage of the algorithm is that derivatives of the field values do not need to be supplied along with the values. The test code has shown good preliminary results and a production version of the algorithm is being implemented in ESMF. The algorithm was developed in collaboration with Amik St. Cyr, a mathematician from the Institute for Mathematics in the Geosciences (IMaGe) at NCAR. The conservative algorithm is expected to be released in early 2010.

Overall, the regrid capability in ESMF has grown increasingly flexible, with options to generate weights on-line or offline, and in parallel or serial. Currently the on-line

version of regridding supports all the grids that ESMF does (structured/unstructured), while the off-line utility only supports single-patch logically rectangular grids. The work needed to create interfaces for the other grid types in the off-line version is straightforward.

The items that were identified as high priority last year were fully or mostly completed and will be included in upcoming releases (C interfaces for Mesh, regridding for Mesh, observational data streams, conservative regridding). However, a shortcut for a physical-space representation of multi-patch grids was not completed; since these grids can be represented in ESMF using lower-level data structures, this tends to slip down the priority list. The implementation of exchange grids is expected to rely upon the implementation of the conservative regridding implementation, and it is still pending as well.

6.2 Improve usability

Measures of success:

- 100% test coverage of framework methods.
- Delivery of a release that further improves consistency of behavior and interfaces.
- Complete sufficient C interfaces to meet customer needs.
- Maintain or reduce the number of open bug reports and feature requests..

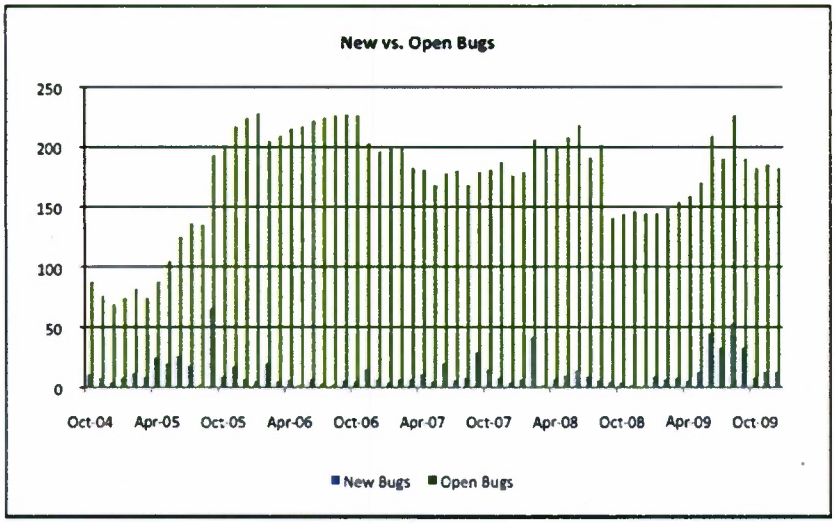
Actual performance, outputs, and outcomes:
Test coverage is at 100% , meaning that all public methods have at least one test (e.g., this is not a 100% guarantee of system correctness).

The 4.0.0r release included a number of improvements for consistency of behavior and interfaces, including the introduction of standard error handling to Mesh class methods, and standardized handling of third-party libraries.

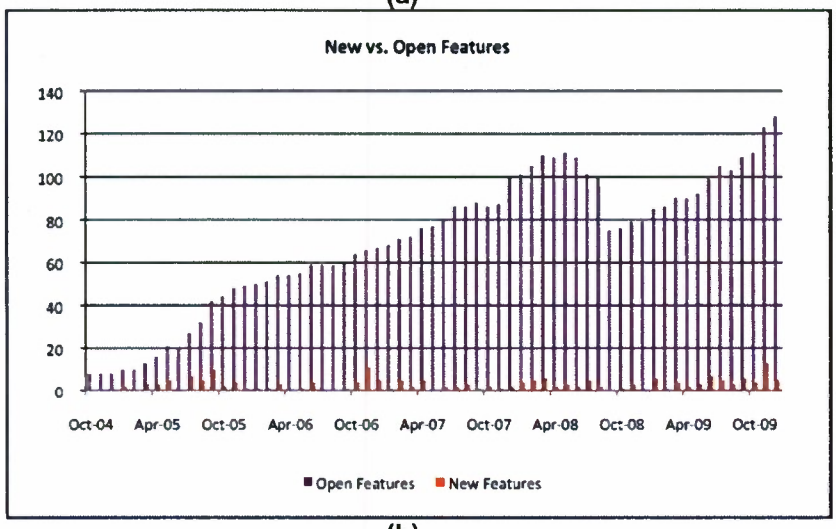
As mentioned in the previous section, C interfaces for the Mesh class were delivered with 4.0.0r in order to complete the pWASH123-ADCIRC coupling for BEI.

Figure 1 (a) shows that the number of open bug reports once again grew after a concerted effort reduced the number by 40% at the end of 2008. Intensive testing before the 4.0.0r public release resulted in numerous new reports. The ESMF team addressed many of these before the release, and others will be fixed in a forthcoming patch. Many of the bugs that remain relate to gaps or deficiencies in documentation. The plan is to address these in 2010 in the ESMF v5.0.0 release.

Figure 1 (b) shows that the 30% decrease in feature requests at the end of 2008 wasn't sustained. The number of open requests increased steadily through 2009, eventually exceeding the previous peak. In general, new features were prioritized lower than bug fixes and completion of the capabilities outlined in the *ESMF Strategic Plan*, and the steady stream of requests simply came in faster than they could be processed. Exceptions were made for new features that were required to satisfy application milestones.



(a)



(b)

Figure 1. Bug and feature request metrics. Following a major reduction at the end of FY09, the number of bugs and feature requests inched up again. Chart (a) shows the number of open ESMF bug reports, chart (b) the number of ESMF feature requests.

6.3 Provide ESMF training and support

Measures of success:

- Hold two training classes during FY2009.
- User comments, surveys, and/or evaluations show that ESMF customers are satisfied with support, training, and documentation.
- Produce a journal paper on ESMF.
- Develop an Outreach Plan to promote use of the framework.

Actual performance, outputs, and outcomes:

A "Getting Started" page was added to the ESMF website, in order to lay out concepts and tasks required for adoption as simply as possible for scientific users. A system test showing a complex ensemble example was added, including ensemble members running both sequentially and concurrently within the same application. Additional examples were added to the Mesh documentation, and improvements

continued to be made to the overall documentation based on support requests and other customer feedback. Based on customer comments, they are increasingly satisfied with documentation quality.

The ESMF team contributed to a journal article entitled "Integrated Modeling of the Battlespace Environment" submitted to the Computing in Science and Engineering journal (lead author Tim Campbell). The ESMF also participated in a paper entitled "A Scientific Workflow Implementation for Earth System Science Related Applications," submitted to the Earth Science Informatics journal, that described aspects of the ESMF-enabled Community Climate System (lead author Turuncoglu). Several book sections were submitted on ESMF for a Springer volume entitled "Earth System Modelling Strategies and Software" (lead author for sections DeLuca; editors Budich and Redler), and also to a volume entitled Handbook of Environmental Fluid Dynamics (lead author for sections DeLuca; editor Fernando).

Tentative arrangements were made for a training session at NCAR in late summer 2009; however, the session was deferred due to the effort and arrangements required in moving the project from NCAR to NOAA. The Outreach Plan was also deferred.

6.4 Develop software utilities and links to science gateway services

Measure of success:

- Delivery of a public ESMF release that includes new features for existing utilities, prioritized in response to user input.

Actual performance, outputs, and outcomes:
ESMF 4.0.0r contained an initial implementation of an ESMF I/O class, but it still requires development to be usable by production applications.

A student intern from the University of Michigan, Peter Bosler, collaborated with NRL to produce a version of COAMPS that used the ESMF Attribute class to instrument the model with metadata. A student visitor from Istanbul Technical University, Ufuk Turuncoglu, did the same for CCSM, and embedded this version in an automated workflow that configured the model, ran it, and documented the run. These projects are building towards an increased level of automation and semantic interoperability that will be an important element of the next ESMF development cycle. Other science-gateway projects are briefly outlined in Appendix C.

6.5 Framework optimization and porting

Measures of success:

- Minimal performance burden for working code. (Target <5% overhead in component overhead and regridding methods.)

Actual performance, outputs, and outcomes:
Optimizations were also performed on the parallel search algorithm used in generating interpolation weights. This resulted in an order of magnitude reduction in

the time required for the cases that were tested. A report on this optimization is being prepared and will be posted to the performance page on the ESMF website in 2010.

In 2008, initial tests of the sparse matrix multiply, the main communication kernel for regridding, were performed out to 16K processors. A variety of data structures capable of representing a set of 2D fields were evaluated, including Arrays and ArrayBundles. The report for this has been completed and the analysis is posted at: http://www.esmf.ucar.edu/metrics/performance/timing_0901_asmm.pdf

The study showed low absolute times for the communication overall: less than a few msecs for all configurations at more than 128 processors.

Users and internal tests indicate that continued development has not degraded performance and ESMF still represents <5% overhead for most applications.

6.6 Advance community adoption

Means, strategies, and actions:
Assist in the development of new, coupled ESMF applications and the transition of these applications to routine use and operations.

Measures of success:
- Number of ESMF components available. A goal for FY2009 was completion of an ESMF version of CCSM4.
- Number of ESMF applications in routine use or operations. The goal for FY2009 include having at least two more ESMF codes transition to production or operations.
- Number of programs based on ESMF.

Actual performance, outputs, and outcomes:
The ESMF version of CCSM was completed, There are now about 90 ESMF components that have been implemented.

- The WRF code has had optional ESMF bindings in their distribution since December, 2006.
- The NASA GEOS-5 atmospheric general circulation model based on ESMF has been in production since 2005.
- The NCEP GFS with ESMF was put into operations in August, 2006.
- The coupled HYCOM and CICE model using ESMF is now in routine use at the Naval Research Laboratory.
- The COAMPS and NCOM application using ESMF components and coupling has been in use since 2007.

MAP, BEI and NUOPC are the largest programs to date that have been based on ESMF.

7 Project plan evaluation measures for FY2010

The sections below describe key metrics and goals for FY2009.

7.1 Develop software for grid representation and regridding

Measures of success:

- Delivery of an ESMF release that includes the ability to represent and regrid multi-tile grids and exchange grids.
- Delivery of an ESMF release that offers integrated conservative regridding.
- Improved integration of ESMF with external regridding capabilities, including an updated version of SCRIP and libCF.

7.2 Improve usability

Measures of success:

- Delivery of a release with highly consistent interfaces and behavior, ready to be frozen for backwards compatibility.
- Maintain or reduce the number of open bug reports and feature requests.

7.3 Provide ESMF training and support

Measures of success:

- Deliver on-line training materials to accompany the ESMF v5 release.
- User comments, surveys, and/or evaluations show that ESMF customers are satisfied with support, training, and documentation.
- Produce one or more journal papers on ESMF.
- Develop an Outreach Plan for 2010-2015 to promote use of the framework.

7.4 Develop software utilities and science gateway services

Measures of success:

- Delivery of a public ESMF release that includes new features for existing utilities and an I/O library.
- Continued development of ESMF Attributes, including a more general and robust XML write capability.

7.5 Framework optimization and porting

Measures of success:

- Minimal performance burden for working code. (Target <5% overhead for ESMF component and regridding methods vs. native packages.)
- Continued demonstration of performance viability for petascale and other emerging computing architectures.
- Requested ports delivered.

7.6 Advance community adoption

Measures of success:

- Number of ESMF components available. A goal for 2010 will be successful completion of all the BEI coupled applications.
- Number of ESMF applications in routine use or operations. Goals for FY2010 include having at least two more ESMF codes transition to production or operations.
- Define a technical and programmatic relationship between ESMF and other standard community interfaces, particularly OpenMI in the hydrology domain.

8 Impact of the ESMF project

Widespread use of ESMF represents a paradigm shift in the way weather and climate models are constructed. Through ESMF standard interfaces, community governance, and shared tools, large centers are more easily able to collaborate on infrastructure needs and exchange codes. The end result is an Earth science community better equipped to explore basic research issues and to answer questions about the changing environment.

9 Sponsors

Core ESMF development is sponsored by the NSF, NASA, NOAA, and the Department of Defense. In addition, a variety of ESMF-based application adoption projects have been sponsored by NASA, NOAA, the U.S. Geological Survey/Department of the Interior, and other agencies and institutions.

Appendix A: Table of Acronyms

ADCIRC	Advanced Circulation Model for Coastal Ocean Hydrodynamics
AR5	IPCC 5th Assessment Report
BEI	Battlespace Environments Institute
CCSM	Community Climate System Model
CICE	Los Alamos sea ice model
CMIP5	5th Coupled Model Intercomparison Project
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System
CoG	Commodity Governance project
CSDMS	Community Surface Dynamics Modeling System
ESMF	Earth System Modeling Framework
FMS	Flexible Modeling System
GEOS-5	Goddard Earth Observing System Model
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	Global Forecast System
GIP	Global Interoperability Program
GO-ESSP	Global Organization of Earth System Science Portals
HYCOM	Hybrid Coordinate Ocean Model
IMaGe	Institute for Mathematics in the Geosciences
IPCC	Intergovernmental Panel on Climate Change
MAP	Modeling Analysis and Prediction program
MAPL	Modeling Analysis and Prediction program Layer
METAFOR	common Metadata For climate modelling digital repositories
MOM4	Modular Ocean Model 4
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NEMS	NOAA Environmental Modeling System
NESII	NOAA Environmental Software Infrastructure and Interoperability group
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSF	National Science Foundation
NUOPC	National Unified Operational Prediction Capability
NWP	Numerical Weather Prediction
PCMDI	Program for Climate Model Diagnosis and Intercomparison
pWASH123	parallel WAterSHed 1-2-3D model
ROMS	Regional Ocean Modeling System
SCRIP	Spherical Coordinate Interpolation and Remapping Package
SWAN	Simulating WAves Nearshore model
SWAT	Soil Water Analysis Testbed
WRF	Weather Research and Forecast model

Appendix B: Current and Pending Support, ESMF and Curator

Program	Sponsor	Period of Performance
Battlespace Environments Institute Infrastructure Development	DoD	$1M/yr; end 12/10
Modeling Analysis and Prediction Program Infrastructure Development and Curator	NASA	$800K/yr; end 12/10
Science Gateway Development	NSF TeraGrid	$50K/yr; 8/09-8/11
Curator Portal Workspaces and Commodity Governance (CoG)	NSF CISE	$300K/yr; 2/10-2/13
NUOPC	NOAA/DoD	TBD/yr; 3/10-March 3/15
Global Interoperability Program	NOAA	$1M/yr; 6/09-TBD

Appendix C: 2009 Curator Projects

Project	Sponsor(s)	Partners	Status
1. Earth System Grid gateway development for display of model metadata for CMIP5/AR5 runs **Why**: climate data distribution	NOAA and NASA Curator	ESG, PCMDI, EU METAFOR, NCAR, Georgia Institute of Technology	Delivered in beta ESG release 1/10
2. GUI and workflow for CCSM and other climate model runs **Why**: easier execution of climate models	NSF and GIP	NCAR, Purdue, ESG	Project initiated in 11/09
3. CAM coupling with Soil Water Analysis Testbed (SWAT) model to demonstrate ESMF interaction with OpenMI-based hydrology codes **Why**: local application of climate model information	NASA Curator	CUAHSI, USC	In progress, estimated completion 9/10
4. COAMPS metadata instrumentation to show model self-documentation **Why**: working towards NUOPC interoperability criteria	NCAR SIParCS internship	University of Michigan, NRL	Prototype completed 9/09, will be used in NUOPC
5. Demonstration of ESMF write of CUAHSI hydrology metadata, shows how ESMF applications can produce data for a hydrology portal **Why**: local application of climate information	NCAR SIParCS internship	Louisiana State University, CUAHSI	Prototype completed 9/09, may be used in CAM-SWAT project (3)
6. Self-documentation of CCSM in a Kepler workflow **Why**: easier execution of climate models	Istanbul Technical University	Istanbul technical University, NCAR	Prototype completed 9/09, will be used in (2)

7. Development of workspaces and on-line governance for community modeling, esp. model comparison and validation with observations **Why**: preparation for larger, more diverse communities who need Earth system models and outputs	NSF CISE	University of Michigan, CSDMS, NCAR, University of Colorado	Project about to begin in 2/10
8. Integration of ESMF with the Eclipse Modeling Framework **Why**: easer development of coupled models	NSF fellowship	Georgia Institute of Technology (Curator minimally involved)	Prototype completed, may be used in compliance checking